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RESEARCH MEMORANDUM

FREE-FLIGHT INVESTIGATION AT TRANSONIC AND SUPERSONIC SPEEDS OF THE ROLLING EFFECTIVENESS OF A THIN, UNSWEPT WING HAVING PARTIAL-SPAN AILERONS

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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SUMMARY

An investigation of the rolling effectiveness at transonic and supersonic speeds of a thin, unswept wing having partial-span ailerons has been made by means of rocket-propelled test vehicles. The results showed that with 4.6° aileron deflection, the only deflection tested, the rolling effectiveness decreased abruptly in the Mach number range from about 0.92 to 0.97. At supersonic speeds the rolling effectiveness was considerably lower than at subsonic speeds. The direction of roll was in the correct sense over the entire Mach number range investigated.

INTRODUCTION

In the course of an investigation of wing-aileron rolling-effectiveness characteristics at transonic and supersonic speeds being conducted by the Pilotless Aircraft Research Division of the Langley Laboratory, utilizing rocket-propelled test vehicles in free flight, a thin, unswept wing having partial-span ailerons was tested. The wing tested had zero sweepback at the 50-percent-chord line, an aspect ratio of 4.0, a taper ratio of 0.5, and employed modified symmetrical double-wedge airfoil sections of 4.6-percent thickness ratio normal to the 50-percent-chord line. The ailerons had a constant chord equal to 35 percent of the wing-tip chord and extended over the outboard 25 percent of the wing semispan. Two identical models having 4.6° aileron deflection were tested. The tests, which were made by means of the free-flight technique described in references 1 and 2, permit the evaluation of the wing-aileron rolling effectiveness over the Mach number range from about 0.6 to 1.8 at relatively large scale. The tests were made during May 1948.

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SYMBOLS

$pb/2V$	wing-tip helix angle, radians
p	rolling velocity, radians per second
b	diameter of circle swept by wing tips
V	flight-path velocity
C_D	drag coefficient based on the total exposed wing area of 1.563 square feet
δ_a	deflection of each aileron measured in plane normal to chord plane and parallel to center line of test vehicle, degrees
R	Reynolds number based on average exposed wing chord of 0.546 feet
M	Mach number
m_θ	wing torsional-stiffness parameter $\left(\frac{m}{\theta}\right)$
m	concentrated couple applied near wing tip in plane parallel to model center line and normal to wing chord plane, inch-pounds
θ	angle of twist produced by m at any section along wing span in plane parallel to model center line and normal to wing chord plane, radians

TEST VEHICLES AND TESTS

The general arrangement of the test vehicles is shown in figures 1 and 2 and additional pertinent information is given in table I. The fuselage, which was constructed mainly of balsa wood and pine, had a plexiglass nose which contained a small radio transmitter designated "spinsonde." The wings were constructed of 24S-T aluminum alloy. The measured torsional-stiffness characteristics of two of the wings tested are shown in figure 3. The degree of torsional stiffness indicated by the curves of figure 3 has been shown by tests reported in reference 2 to be sufficient to minimize the effects of wing twisting so that the main aerodynamic effects are not obscured. The airfoil section parallel to the test vehicle center line was derived from a basic symmetrical double-wedge section of 5-percent thickness ratio modified at midchord with circular arcs to produce a thickness ratio of 4.6 percent.

The aileron deflection was obtained by cutting a $\frac{1}{16}$-inch-wide slot in the wing along the hinge line to a depth of one-half the local thickness. The aileron was then bent to the desired deflection and the slot faired in. Calculations indicate that the change in aileron deflection due to air loads did not exceed 0.2°.

The test vehicles were propelled by a two-stage rocket-propulsion system to a Mach number of 1.9. During coasting flight following burnout of the rocket motor, time histories of the rolling velocity produced by the ailerons (obtained with spinsonde radio equipment) and the flight-path velocity (obtained with Doppler radar) were recorded. These data, in conjunction with atmospheric data obtained with radiosondes, permit the evaluation of the rolling-effectiveness parameter $pb/2V$ as a function of Mach number. The drag coefficient of the test vehicles was obtained by a process involving the graphic differentiation of the curve of flight-path velocity against time. The scale of the tests is indicated by the curve of Reynolds number against Mach number shown in figure 4. A more complete description of the technique is given in references 1 and 2.

ACCURACY

The accuracy of the test results was estimated to be within the following limits:

$pb/2V$ (due to limitations on model constructional accuracy) . . .	± 0.003
$pb/2V$ (due to limitations on instrumentation)	± 0.0005
C_D	± 0.002
M	± 0.005

It will be noted, as pointed out in reference 1, that, owing to the relatively small moment of inertia about the roll axis, the measured values of $pb/2V$ are substantially steady-state values even though the test vehicles were experiencing an almost continuous rolling acceleration and deceleration. Except for abrupt changes of $pb/2V$ with Mach number which occur in the Mach number range from about 0.92 to 0.97, the correction to steady-state conditions is estimated to be within 3 percent. Between Mach numbers of 0.92 to 0.97 the maximum correction corresponding to the maximum attained rolling acceleration of 60 radians per second squared, assuming a damping-in-roll coefficient of 0.2, is 15 percent. The data presented herein have not been corrected for inertia effects.

RESULTS AND DISCUSSION

The results of the present investigation, obtained with three-wing configurations, are shown in figure 5 as curves of $pb/2V$ and C_D as functions of Mach number. Unpublished tests of three- and four-wing configurations have shown that, with regard to rolling-effectiveness characteristics, the interference effects between the wings are small.

As shown in figure 5, the wing-aileron rolling effectiveness was reduced abruptly in the Mach number range from about 0.92 to 0.97. At supersonic speeds the rolling effectiveness is considerably lower than at subsonic speeds. At the maximum Mach number attained (1.92) the rolling effectiveness is about 15 percent of the effectiveness at lowest Mach number for which measurements were obtained (0.74). The direction of roll is in the correct sense over the entire Mach number range.

Also shown in figure 5 is the variation of total drag coefficient with Mach number for the two models tested. It should be noted that the measured total drag coefficient is influenced by interference effects and by the section angle-of-attack distribution caused by model rotation.

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REFERENCES

1. Sandahl, Carl A., and Marino, Alfred A.: Free-Flight Investigation of Control Effectiveness of Full-Span 0.2-Chord Plain Ailerons at High Subsonic, Transonic, and Supersonic Speeds to Determine Some Effects of Section Thickness and Wing Sweepback. NACA RM No. L7D02, 1947.

2. Sandahl, Carl A.: Free-Flight Investigation of Control Effectiveness of Full-Span, 0.2-Chord Plain Ailerons at High Subsonic, Transonic, and Supersonic Speeds to Determine Some Effects of Wing Sweepback, Taper, Aspect Ratio, and Section Thickness Ratio. NACA RM No. L7F30, 1947.

[redacted]

TABLE I

GEOMETRIC CHARACTERISTICS OF TEST VEHICLE

Total exposed wing area, sq ft	1.563
Aspect ratio	[a]4.0
Taper ratio	[a]0.5
Sweepback of 50-percent-chord line, deg	0
Aileron deflection, δ_{α}, deg	4.6
Moment of inertia about roll axis, slug-ft^2	0.0775

[a]Obtained by extending leading edge and trailing edge to center line of test vehicle.

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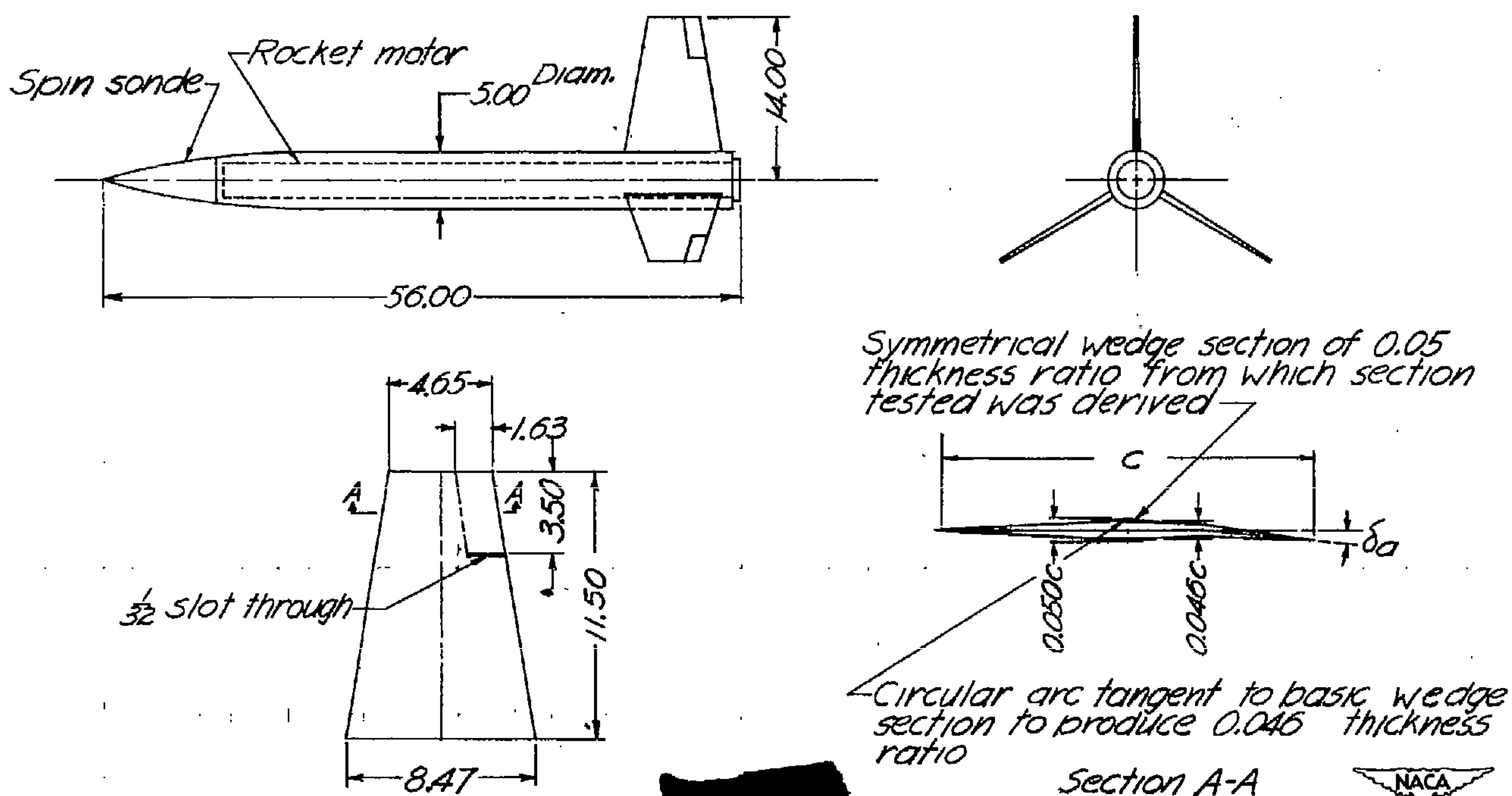

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Figure 1.- General arrangement of test vehicles. Dimensions are in inches.

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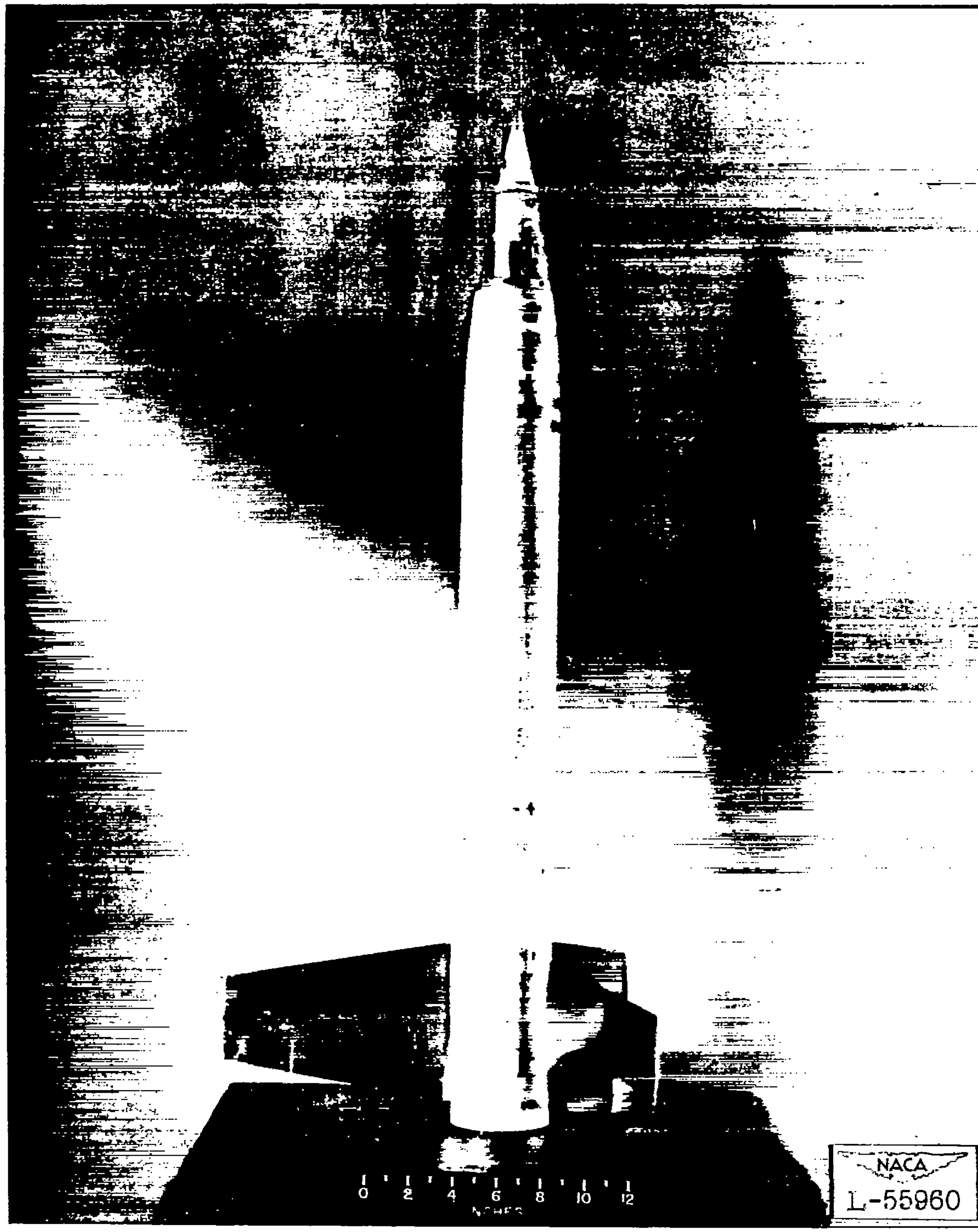

(a) General arrangement.

Figure 2.- Photographs of models.

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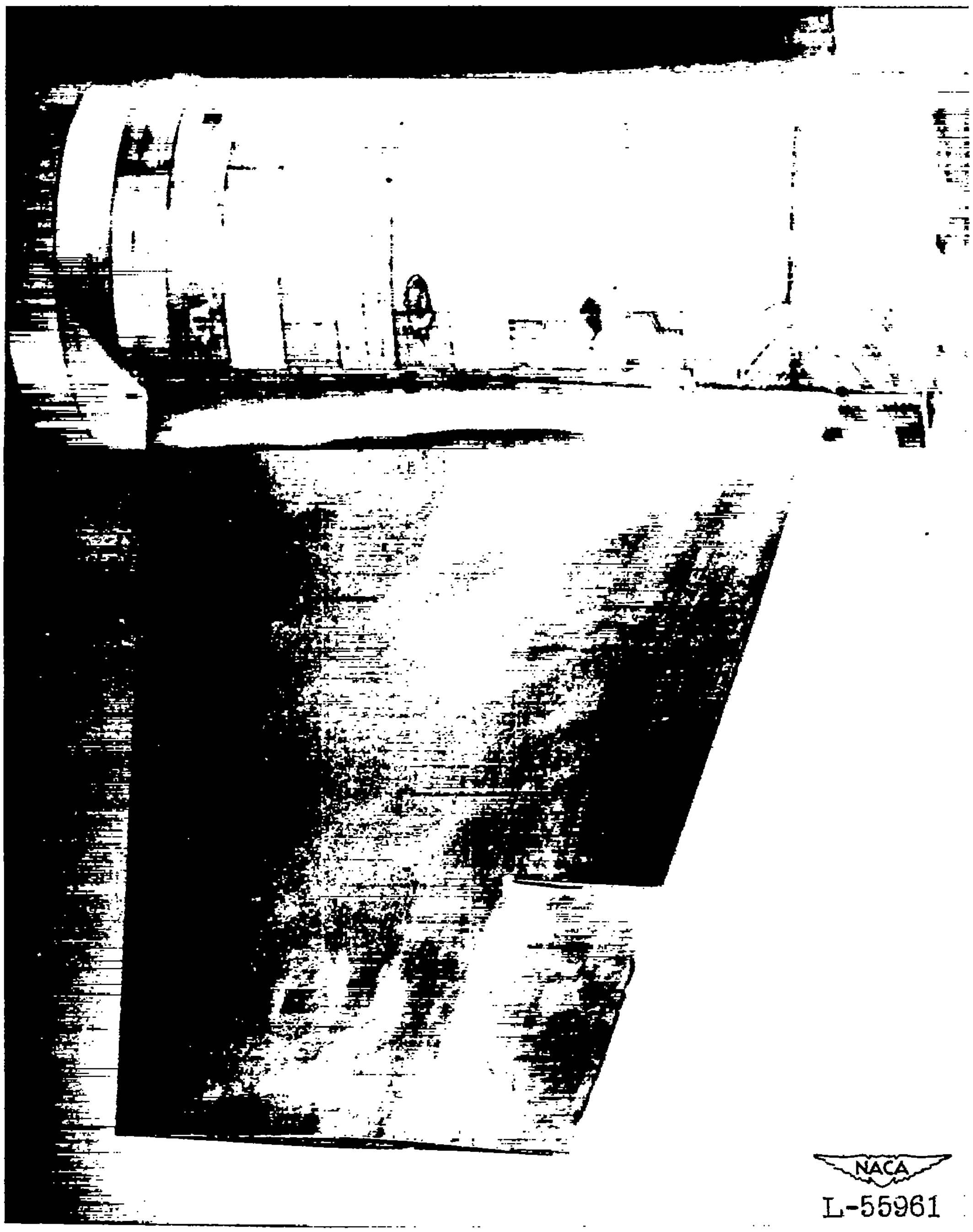

(b) Wing detail.

Figure 2.- Concluded.

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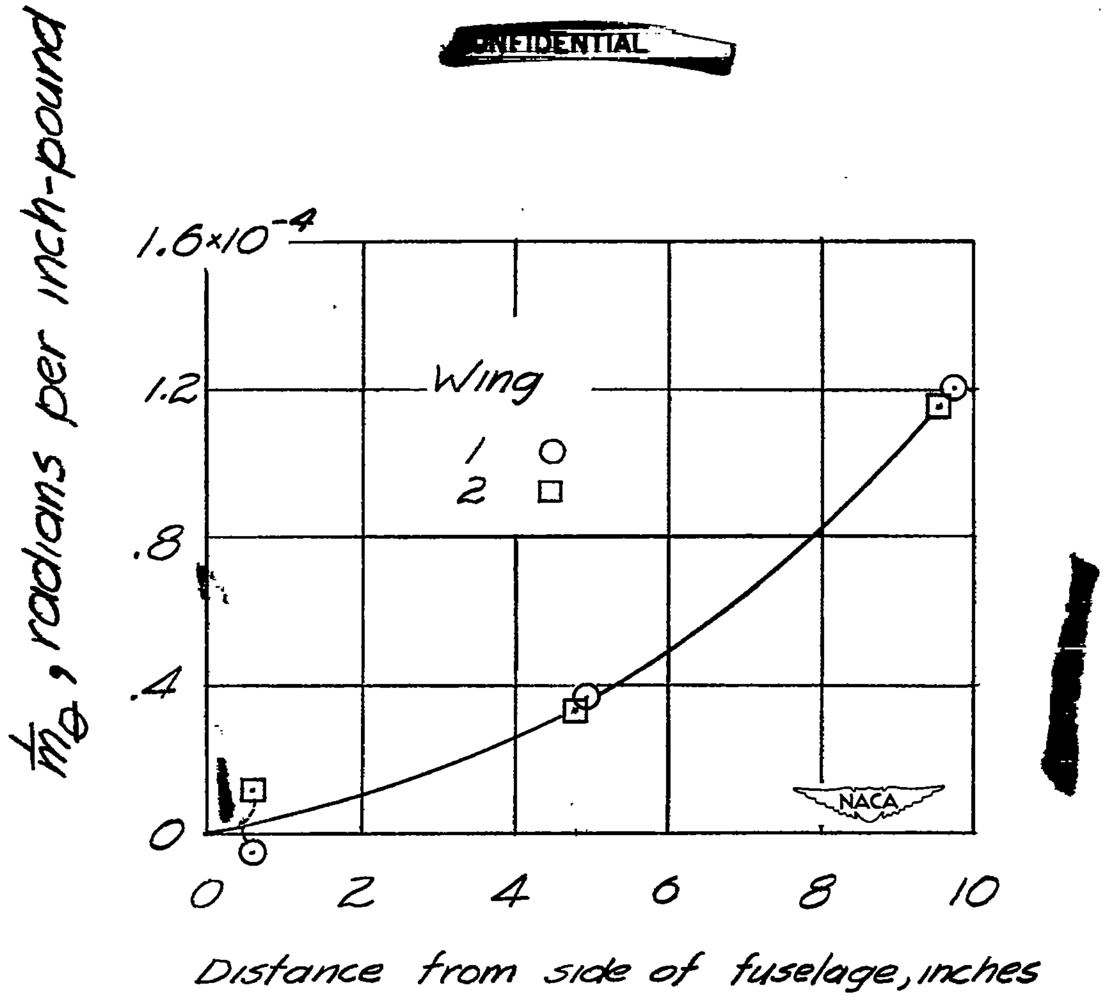

Figure 3.- Wing torsional stiffness characteristics.

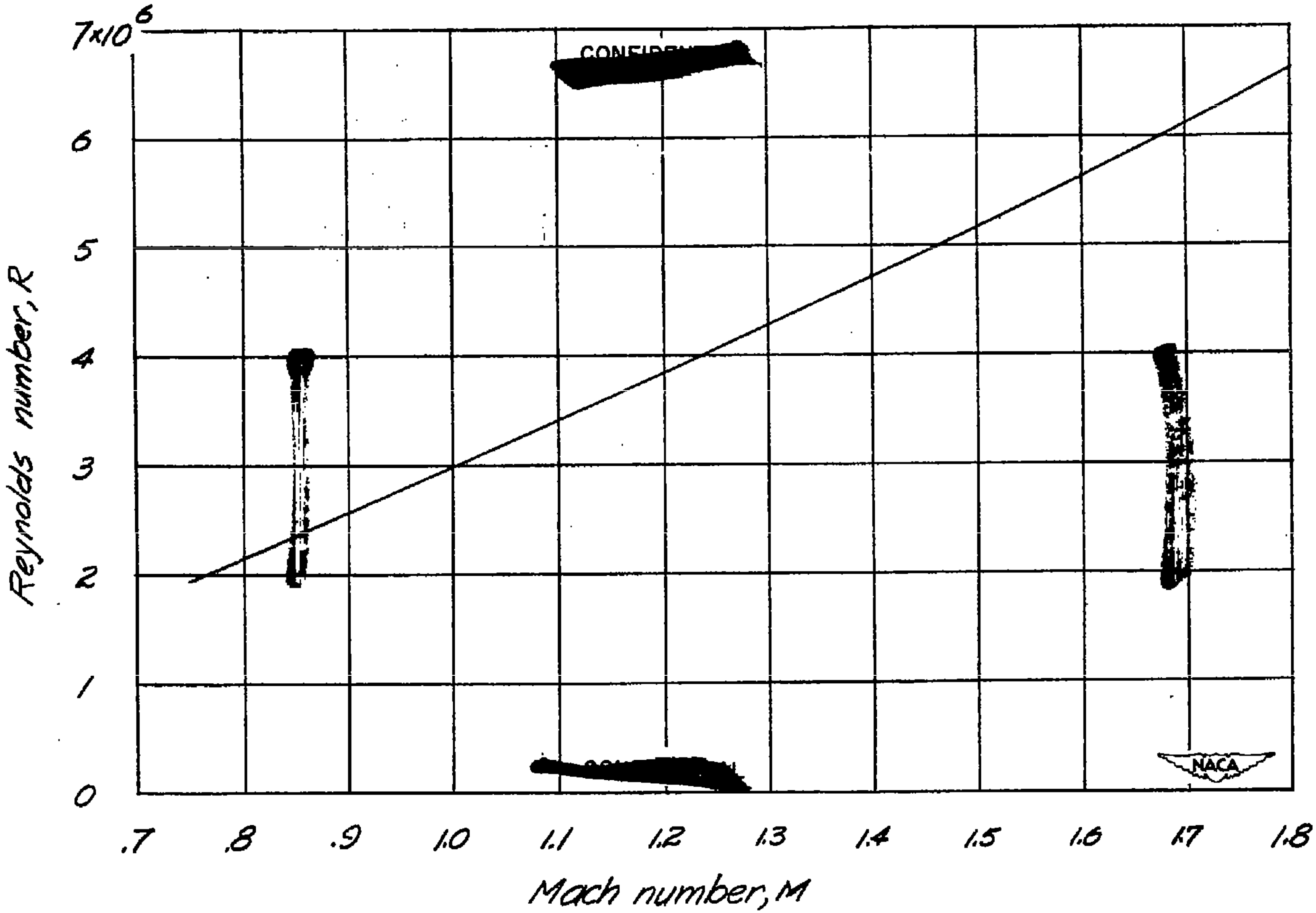

Figure 4.- Scale of tests.

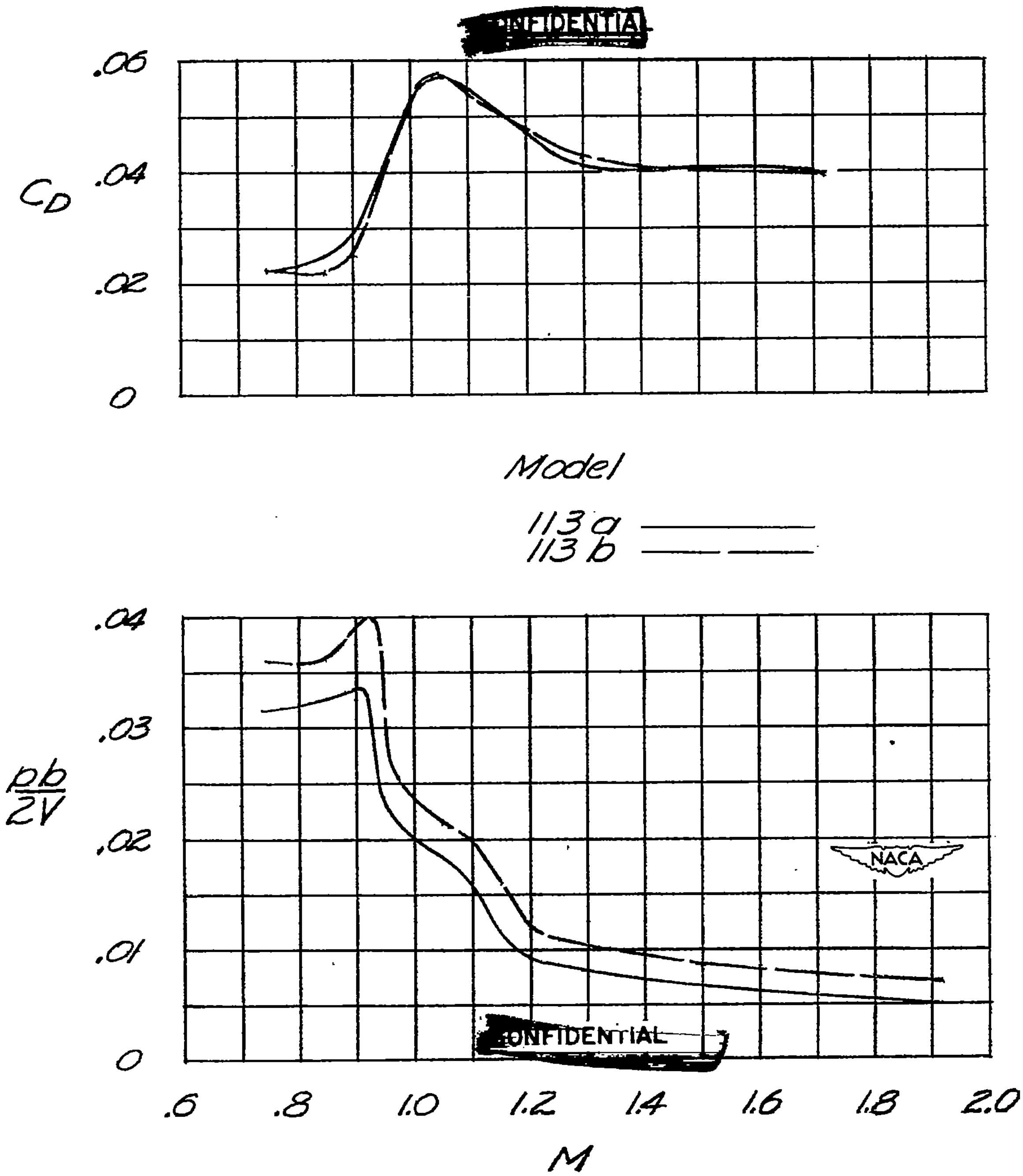

Figure 5 .- Test results. $\delta_a = 4.6°$.